



TECHNICAL COMMENTS FOR CELLULAR AIRBORNE NPRM

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I. Introduction & Summary

V-COMM, L.L.C. has prepared this report in response to the FCC's request for comments regarding the Cellular Airborne Notice of Proposed Rule Making (*Cellular Airborne NPRM*).^{1, 2} This report analyzes the technical issues and potential interference associated with airborne handsets and pico cell operation, in addition to the proposed secondary use of cellular and PCS spectrum to facility a new air-to-ground service. This report provides information into the record concerning the suitability and impact of these proposed uses of spectrum for these air-to-ground and airborne services.

In preparation for this report, V-COMM has analyzed the extensive and comprehensive flight and interference test data that was performed by V-COMM and submitted into the FCC record in the AirCell proceeding (Docket 02-86). V-COMM performed over 10,000 air miles of flight tests with the AirCell air-to-ground system that shares the cellular spectrum, and performed extensive interference tests at terrestrial cellular base stations operating with AMPS, TDMA and CDMA technologies. The results of these tests (air-to-ground flight tests and base station interference tests) represent substantially more test data than any other party has conducted and submitted into the FCC record. The flight tests include a variety of aircraft antennas, aircraft flight patterns, flight altitudes, separation distances and terrestrial base station antennas. The terrestrial base station interference tests represent extensive benchmarking of the real-world impacts to terrestrial base stations. Therefore, the results of these extensive flight tests and interference tests are used to determine the impact and suitability of using the cellular and PCS spectrum for airborne handset, onboard pico cells, and air-to-ground "pipe" operations.

In addition, the results of V-COMM's *Airplane Cabin leakage Study* are analyzed in conjunction with the proposed airborne and air-to-ground services.³ The results of this study indicate that no loss in signal strength will occur for airborne handsets operating at window seats on commercial airplanes. For the 767 aircraft, the signal leakage through the airplane cabin window to the outside environment was relatively unaffected (0 dB loss). For the 737 aircraft, the window presented an increase in signal strength on the order of 3 to 4 dB depending on the frequency band.

¹ The FCC *Cellular Airborne NPRM (NPRM)*, released on Feb 15, 2005, is referenced to the Commission's *Amendment of the Commission's Rules to Facilitate the Use of Cellular Telephones and other Wireless Devices Aboard Airborne Aircraft* (WT Docket 04-435).

² V-COMM, L.L.C. is a wireless telecommunications consulting company with principal members having over 20 years experience in the wireless industry. We have provided our expertise to wireless operators in RF engineering, system design, implementation, performance, optimization, and evaluation of new wireless technologies. We have extensive industry experience in all CMRS technologies. V-COMM's company information and experiences are highlighted in this report's Appendix A, along with biographies of senior members of its engineering team. V-COMM has prepared this report pursuant to a contract with Verizon Wireless and Cingular Wireless.

³ V-COMM has performed airplane signal leakage measurements on two aircraft (Boeing 767 and 737) in the cellular and PCS bands. These tests were performed to measure the signal path leakage through the aircraft cabin to assess the impact of airborne handset operation on terrestrial networks. The results and descriptions are provided in the V-COMM airplane leakage report (*Airplane Cabin Leakage Study*) that is submitted in the instant proceeding along with this report.

In regards to the air-to-ground “pipe” application in cellular spectrum using an output power level of 0 dBm (as proposed in the NPRM), the analysis indicates that terrestrial base stations will receive air-to-ground signals substantially above the level shown to cause unacceptable interference to terrestrial networks.⁴ Therefore, the output power level of 0 dBm is substantially too high for the proposed air-to-ground services, and can cause harmful interference to terrestrial networks with aircraft at any altitude.

For example, the air-to-ground signals will be received in the range of 6 to 29 dB above the base station unacceptable interference level, for the altitudes of 5,000 feet and below. At 10,000, 20,000 and 35,000 feet, the interference is received up to 14 dB, 10dB, and 6 dB, respectively, above the unacceptable interference level for the terrestrial base stations. This represents the interference received for just one air-to-ground signal used on one aircraft in view of the terrestrial base station (with an output power limit of 0 dBm & unity gain aircraft antenna). If additional air-to-ground signals or aircraft are present, or if increased power or antenna gain is used in the air-to-ground system, the received interference levels can be significantly higher than indicated in this analysis. For these reasons, the FCC needs to take into account the gain of the aircraft antenna, the number of aircraft within view, and the power level of the air-to-ground system to ensure harmful interference is not caused to terrestrial systems.

In regards to the proposed airborne handset and pico cell operations in cellular or PCS spectrum, the analysis provided shows terrestrial base stations can receive airborne signals substantially above the level shown to cause unacceptable interference to terrestrial networks. As indicated, the airborne handset signals received at terrestrial base stations rises to the level of unacceptable interference for the case with two airborne handsets at window seats even at the aircraft altitude of 35,000 feet and handset power level of 0 dBm EIRP. Therefore, due to the very strong receive signal levels that can be expected from airborne handsets, the FCC should not authorize this airborne service at the 0 dBm level, as it can cause substantial harmful interference to the terrestrial networks with aircraft at any altitude.

Therefore, the airborne handset and pico cell systems need to provide additional attenuation of the signals toward the ground networks. Methods to accomplish additional attenuation of the airborne signals include one or more of the following methods: airplane window shielding; restricting airborne use to higher altitudes; operating airborne handsets in PCS bands for additional propagation loss; frequency coordination with ground networks to facilitate channels that make accommodations for airborne use; and operating airborne handsets at lower power

⁴ The terms of “unacceptable interference” and “unacceptable interference level” are used in this report for analysis purposes, and to provide an assessment of the impact of airborne services to terrestrial networks. This level was developed from interference tests performed at a suburban cellular base station operating with standard cell site equipment. It is the level that is shown to cause impairments in system performance at the terrestrial base station tested. Other base stations operating with other technologies, with more sensitive receivers, advanced equipment, or located in other market environments may be more sensitive to interference. Also, interference to in-building users can be expected to be more sensitive than the levels represented herein. Therefore, this level of “unacceptable interference” is only applicable to this report and analysis performed herein, to be used to assess the impact of the proposed airborne services.

levels (i.e. below 0 dBm). By utilizing these methods the necessary attenuation of airborne signals may be achieved.

For example, with two airborne handsets operating at the radiated power level of 0 dBm EIRP and 10,000 feet, 15 dB of additional attenuation is needed for the cellular band, and 8 dB of additional attenuation is needed for the PCS band, in order to prevent unacceptable interference to the terrestrial networks. This represents the handset power limit of -15 dBm EIRP for the cellular band, and -8 dBm EIRP for the PCS band, to prevent unacceptable interference to the terrestrial networks. These power levels are significantly lower than the minimum power level used by many commercial handsets today. Therefore, window shielding or other methods are required to attenuate the signals below the levels that can interfere with the terrestrial networks. The Commission must also consider the potential for interference caused by airborne handsets that are not controlled by the onboard pico cell, and are operating at handset's maximum power levels (i.e. +30 dBm, or higher in some cases). These instances have the potential to cause devastating interference to tens of thousands of subscribers served by thousands of terrestrial sites that are receiving airborne signals under line-of-sight conditions for a single aircraft and flight path. To prevent airborne handsets from acquiring terrestrial signals and placing calls at maximum power the following issues must be considered: 1.) the onboard pico cell may need to support multiple handset types, technologies, and spectrum bands; 2.) handsets will need to be re-programmed and preferred roaming lists need to be updated; 3.) handsets may need modifications to incorporate airplane friendly modes that have visual indications of positive control of the onboard pico cell; 4.) roaming agreements and connections will be needed with the terrestrial wireless service providers; and 5.) aircraft window shielding and other techniques may be required to prevent airborne handsets from acquiring terrestrial signals in flight and transmitting at maximum power levels.

To address the significant interference potential and compatibility issues associated with airborne uses of cellular and PCS spectrum, the commercial mobile radio service (CMRS) licensees must be involved. CMRS licensees have the ability to ensure that airborne handsets are controlled by the onboard pico cells and not operating at maximum power levels, and to ensure that the airborne systems that will not degrade the reliability of terrestrial networks.

CMRS licensees can also provide spectrum leasing, roaming agreements & connections, handset re-programming issues, updating handset PRL lists, necessary modifications to handsets (including airplane friendly modes and power limiting airborne handsets), customer & airline education, coordination and resolution of problems, frequency coordination and selection, testing and verification, and other arrangement to address all the potential interference issues that can result from such implementations. In addition, the service providers are more experienced and capable of successfully implementing other critical services and wireless technologies such as CALEA, Priority Access Systems, E911 Phase 2 location services (assisted GPS and network based solutions), feature compatibility with ground networks, TTY/ hearing aid compatibility, among other wireless operating modes.

II. Airborne Cellular and PCS Transmissions Pose a Significant Interference Threat to Terrestrial Service

A. Interference Caused by Use of Cellular or PCS spectrum for an Air-to-Ground “Pipe” at Low Levels

1. Background & Overview of V-COMM Tests

V-COMM has conducted extensive flight and interference testing that is submitted into the FCC record in the AirCell proceeding. V-COMM has conducted extensive flight testing of the AirCell air-to-ground system that utilizes the cellular spectrum for its operations. In addition, V-COMM has conducted extensive interference tests at terrestrial base stations operating with AMPS, TDMA and CDMA technology. These results are submitted in the FCC record in the AirCell proceeding (submitted on 4/10/2003 in Docket No. 02-86) as engineering reports attached to filings of the cellular service providers AT&T Wireless, Cingular Wireless, and Verizon Wireless.⁵

The flight tests include over 10,000 air miles of flight testing of the AirCell air-to-ground system that utilizes the cellular band. Included are a variety of aircraft antennas, aircraft flight patterns, flight altitudes, separation distances and terrestrial base station antennas. This test data represents substantially more air-to-ground flight test data than any other party has conducted and submitted into the FCC record.

The terrestrial base station interference tests represent extensive benchmarking of the interference impacts to terrestrial base stations operating with AMPS, TDMA and CDMA technologies. Measurements included over 10 metrics showing the full impact of interference to the terrestrial base station operating in a suburban market environment. These tests utilized standard base station equipment and operating configurations, and typical network conditions. Tests were performed on live, active cellular systems during daytime hours showing the real-world impact to the cellular system.

Therefore, the results of these extensive and comprehensive flight and interference tests are used determine the impact and suitability of using the cellular and PCS spectrum as an air-to-ground “pipe”, as proposed in the FCC Cellular Airborne NPRM. In addition, they are also utilized to determine the impact and suitability of using the cellular and PCS spectrum for airborne handset and onboard pico cell operations.

⁵ The results of V-COMM’s extensive flight tests and interference tests with AMPS, TDMA & CDMA technologies are filed in the FCC Docket 02-86. The V-COMM report entitled “Engineering Report of the AirCell Compatibility Test” and all its appendices (*V-COMM Engineering Report*) can be found at the following FCC links.

http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6513882998

http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6513882999

http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6513883000

2. Results of V-COMM Flight Tests

From the reported V-COMM flight data, the 90th percentile received signal levels at the terrestrial base station antennas for the fixed-power level (labeled as DPC Disabled) flight tests are used for this analysis to assess the impact of a proposed air-to-ground “pipe” application using cellular or PCS spectrum.

These results represent the 90% worst case signals received (computed from the individual measured data) as the aircraft is flying a uniform flight pattern of 360 degrees around the terrestrial base station’s antennas.⁶ For the omni-directional base station antenna, the 90% received signal level represents the level at which 10% of the signals will be received above this level, and 90% of the signals will be received below this level.

For the terrestrial base station panel antennas, the measured data points at the top of the charts (i.e. the upper 1/3 of RSSI values) represent signal levels received when the aircraft is flying within its 120 degree sector serving area. Therefore, for the base station sector panel antennas, which are used to serve 120 degrees (only 1/3 of coverage area) of a 3-sectored site’s coverage area, the 90% received signal level represents a significantly more percent of time, because the 90% received signal level was computed using flight patterns that included 360 degrees around the panel antenna (including behind the panel antenna). Therefore, the 90% received signal level reported in the V-COMM flight test report represents the level at which about 10% to 30% of the signals will be received above this level for a panel antenna when an aircraft is flying within its 120 degree coverage pattern, and likewise it represents the level at which 70% to 90% of the signals will be below.

Therefore this 90% signal level is used in this analysis as it represents a conservative level below the maximum received signal level at the terrestrial base stations.

The flight test results for the four base station antennas located at the Marlboro terrestrial site are given in the table below.⁷ The received AirCell signal levels are significantly above the level where interference is shown to occur, which was as low as -120 dBm at AMPS, TDMA and CDMA terrestrial base stations, for all aircraft types, altitudes and base station antenna types.⁸

⁶ The terrestrial base station included in this study, which the flight measurements include all 360 degrees in uniform flight patterns around this site, was the Marlboro, NJ terrestrial site. At this site, the terrestrial base station (used in this study) was also co-located with the AirCell Marlboro, NJ site that serves the airborne AirCell terminals.

⁷ These values represent the worst case 90% received signal levels at the four terrestrial antennas at the Marlboro terrestrial cellular base station. The results of these flight tests can be found at pages 150-173 on Figures 9.5-K through 9.5-HH, in the *V-COMM Engineering Report*.

⁸ The four terrestrial base station antenna types used in the flight tests, were the: 1.) horizontally polarized panel antenna (H-POL); 2.) slant 45 degree polarized panel antenna (SL45); 1.) vertically polarized panel antenna (V-POL); 1.) vertically polarized omni-directional antenna (OMNI). The panel antennas were common types used in cellular networks having 90 degree horizontal patterns, and approximately 14 dBi antenna gains. The piston aircraft was used for lower altitudes, which utilizes the AirCell VOR type aircraft antenna mounted on horizontal stabilizer. The jet aircraft was used for higher altitudes, which utilizes the aircraft belly-mounted (bottom of aircraft) AirCell antenna. Both aircraft antennas are assumed to be unity gain.

Aircraft & Antenna Type	Altitude (feet, AMSL)	Terrestrial BTS Received Signal (90% Level)			
		H-POL (dBm)	SL45 (dBm)	V-POL (dBm)	OMNI (dBm)
Piston (VOR)	2,000	-75	-80	-91	-95
Piston (VOR)	5,000	-85	-90	-98	-98
Piston (VOR)	10,000	-90	-95	-103	-102
Jet (Belly)	10,000	-91	-95	-100	-105
Jet (Belly)	20,000	-94	-97	-104	-104
Jet (Belly)	35,000	-98	-100	-109	-108

Table 1: AirCell Signals Received at Terrestrial BTS

3. Results of V-COMM Terrestrial Base Station Interference Tests

V-COMM has conducted extensive real-world interference tests on standard terrestrial base stations operating within a typical suburban market environment. The results of these real-world tests show that *unacceptable interference* occurs at -120 dBm at terrestrial base stations operating with AMPS, TDMA and CDMA technology.^{9, 10} At this level, the interference has raised the interference noise floor of the base station and reduced its operating margin needed to provide reliable service to customers (particularly for in-building users). As observed in the test results with interference received at a level of -120 dBm, the operating margin for AMPS calls was reduced by 7 dB, for TDMA calls it was reduced by 3 dB, and for CDMA calls it was reduced by 1.6 dB.¹¹ This represents a significant reduction in system coverage and capacity, particular for in-building users. It should be noted that these base station interference tests did not include specific tests designed to show the impacts to in-building cellular users, which would have shown more severe and harmful impacts to the networks, than cellular handsets used in

⁹ The terms of “unacceptable interference” and “unacceptable interference level” are used in this report for analysis purposes, and to provide an assessment of the impact of airborne services to terrestrial networks. This level was developed from interference tests performed at a suburban cellular base station operating with standard cell site equipment. It is the level that is shown to cause impairments in system performance at the terrestrial base station tested. Other base stations operating with other technologies, with more sensitive receivers, advanced equipment, or located in other market environments may be more sensitive to interference. Also, interference to in-building users can be expected to be more sensitive than the levels represented herein. Therefore, this level of “unacceptable interference” is only applicable to this report and analysis performed herein, to be used to assess the impact of the proposed airborne services.

¹⁰ GSM technology was being deployed at the time these base station interference tests were conducted, and as a result GSM was not included in these base station interference tests. However, the same -120 dBm “unacceptable interference” level with a 1 dB margin for preventing it (referenced to the received interference level of -121 dBm) is assumed for GSM networks as well, for this analysis. This level is 3 dB below the system noise floor of a GSM base station (kTB for 200 kHz = -121 dBm + 3 dB noise figure = -118 dBm), and can result in a 1.76 dB increase in the base station interference noise level. UTMS technology was not tested either, as it was not available at the testing time. For this case, the same interference levels are also assumed for UMTS base stations, due to the similarities to CDMA technology, such as both technologies having the same receive sensitivity levels.

¹¹ A summary of the results of the base station interference tests is listed in Section 4.5 of the *V-COMM Engineering Report* on pages 71-73.

vehicles on the street. Also, these interference tests did not utilize more sensitive base station equipment (such as tower-top LNA, or superconductor receive equipment) or sites in rural markets, which would have shown more sensitivity to interference and caused interference at lower receive levels.

Therefore, the -120 dBm is considered the level of “unacceptable interference” for terrestrial base stations for this analysis.¹² In addition, at least a 1 dB margin below this level is assumed to be needed to prevent this unacceptable interference from occurring. Therefore, for the assessment of an air-to-ground pipe application in the cellular or PCS spectrum, the air-to-ground signals must be received at or below -121 dBm at the terrestrial cellular and PCS base stations.

4. *Assessment of Air-to-Ground Operations, Impact to Terrestrial Cellular & PCS Networks*

This section addresses the assessment of air-to-ground (ATG) operations and impacts to terrestrial cellular and PCS networks. As shown in the test results (previous table above), the AirCell signals received at terrestrial cellular base stations are significantly above the level of unacceptable interference for the AMPS, TDMA and CDMA base stations. The AirCell signals are received above this level on the order of 11 to 45 dB depending on the altitude of the aircraft and type of base station antenna employed, as shown in the table below.

Aircraft & Antenna Type	Altitude (feet, AMSL)	AirCell Signals Received, in Decibels Above BTS Unacceptable Interference Level			
		H-POL (dB)	SL45 (dB)	V-POL (dB)	OMNI (dB)
Piston (VOR)	2,000	45	40	29	25
Piston (VOR)	5,000	35	30	22	22
Piston (VOR)	10,000	30	25	17	18
Jet (Belly)	10,000	29	25	20	15
Jet (Belly)	20,000	26	23	16	16
Jet (Belly)	35,000	22	20	11	12

Table 2: AirCell Signals Received, Above BTS Interference Level

It should be noted that the output power level of the AirCell mobile station was +16 dBm into the aircraft antenna. This was measured by V-COMM after flight tests were completed, for the channel used in the flight testing, and is referenced to the input of the aircraft antenna. The AirCell aircraft antenna gain was not measured, but was assumed to be approximately unity gain (0 dBd, or +2 dBi). Therefore, the transmitted signal of the AirCell aircraft unit represents the radiated power level of approximately +18 dBm EIRP.

In consideration of an air-to-ground application in cellular spectrum using an output power level of 0 dBm, as proposed in the NPRM referenced to the aircraft antenna input, terrestrial base stations (BTS) can expected to receive the air-to-ground signals approximately 16 dB lower than

¹² Using this “unacceptable interference level” may have the effect of limiting the technology and advancements in future equipment that may operate at lower noise levels and improved spectrum efficiency.

AirCell signals. This assumes air-to-ground systems do not employ higher antenna gain than the AirCell aircraft antenna, which was unity gain. Adjusting the flight test results (table above), for a 0 dBm ATG output power level, shows the air-to-ground signals received in the range of 6 to 29 dB above the BTS unacceptable interference level, for the altitudes of 5,000 feet and below. As shown in the table below, at 10,000, 20,000 and 35,000 feet, the interference is received up to 14 dB, 10dB, and 6 dB, respectively, above the unacceptable interference level for the terrestrial base stations. Also, for the jet aircraft at 10,000 feet, the results for the SL45 and V-POL base station antennas show interference received 9 and 4 dB above the level of unacceptable interference.

Aircraft & Antenna Type	Altitude (feet, AMSL)	Air-to-Ground Signals Received, in Decibels Above BTS Unacceptable Interference Level			
		H-POL (dB)	SL45 (dB)	V-POL (dB)	OMNI (dB)
Piston (VOR)	2,000	29	24	13	9
Piston (VOR)	5,000	19	14	6	6
Piston (VOR)	10,000	14	9	1	2
Jet (Belly)	10,000	13	9	4	-1
Jet (Belly)	20,000	10	7	0	0
Jet (Belly)	35,000	6	4	-5	-4

Table 3: ATG Signals Received (at 0 dBm), Above BTS Interference Level

Therefore, the proposed output power level of 0 dBm in the FCC NPRM is too high, and substantially above the level shown to cause unacceptable interference to terrestrial networks.

In addition, these flight test results show the interference received for just one air-to-ground channel or signal used on one aircraft in view of the terrestrial base station, with an output power limit of 0 dBm into the aircraft antenna, and a unity gain aircraft antenna. If additional air-to-ground signals or aircraft are present, or if increased power or antenna gain is used in the air-to-ground system, then the received interference levels may be significantly higher than the analysis data indicates above.

5. Aircraft Antenna Gain

Aircraft antennas with additional gain above unity gain would need to operate at lower levels than indicated in this analysis. The output power reduction would need to be on the same order of the increase in gain of the aircraft antenna above a unity gain antenna. Therefore, the FCC must take into account the gain of the aircraft antenna, in addition to the power into the aircraft antenna.

6. Multiple Channels & Multiple Aircraft

The total received power level at the terrestrial base station will depend on the number of aircraft within view and channels that are co-channel with the terrestrial bases stations. For example, if an air-to-ground system is using two channels within a 1.25 MHz CDMA channel, or two channels within a 200 kHz GSM channel, the total received power level at the terrestrial base stations is increase by 3 dB. Similarly, if two airplanes using air-to-ground transmission are within view of a terrestrial base station, then the signal level at the base station can be increased

by 3 dB. And, if both are occurring, i.e. two channels per aircraft and two aircraft within view, the received signal will be increased by 6 dB (above the levels received for 1 aircraft and 1 channel used).

7. Air-to-Ground Operations above 10,000 feet

If air-to-ground use of cellular or PCS spectrum is restricted to altitudes above 10,000 feet and in areas where the terrestrial networks are not using horizontally polarized receive antennas, the results for the slant-45 base station antenna (SL45) can be used (from table above), after accounting for a multiple aircraft factor. For the SL45 antenna at 10,000 feet, and assuming 2 aircraft with 2 channels used in each (6 dB increase), an air-to-ground output power limit of -16 dBm would be required to prevent unacceptable interference to cellular networks.¹³ For PCS frequencies, the propagation loss is approximately 7 dB additional loss than cellular frequencies. Therefore, an air-to-ground output power limit of -9 dBm (at 10,000 feet and above) would be required to prevent unacceptable interference to PCS networks that do not use horizontally polarized receive antennas.

8. Other Air-to-Ground System Isolation Factors

The Cellular Airborne NPRM (paragraphs 24-25) requests additional information on the isolation factors and effects of using directional or smart antennas, or diversity in antenna polarization for the aircraft antenna, and the ability to increase the output power level of the airborne air-to-ground transmitter that would share the cellular or PCS spectrum. In analysis of the isolation factors, they do not appear to be effective in reducing the receive signal levels at the ground networks for the following reasons. In addition, any specific proposal must be thoroughly evaluated on a case-by-case basis for the full impact to the ground networks, when analyzing the effects of increasing the transmitting signal of aircraft air-to-ground systems.

a.) Antenna Polarization Effects

V-COMM has studied the effects of various antenna polarizations and impacts to the received power levels at the terrestrial base stations, from the extensive set of air-to-ground flight data that was collected in 2000-2001. As described in section 7.2 of the *V-COMM Engineering Report* (filed in FCC record in AirCell proceeding), the effects three different base station antenna polarizations are studied, from the extensive set of flight data collected with a horizontally polarized aircraft antenna. The results show the strongest level received at the base stations antenna with the same polarization (horizontal), and lower levels received at slant 45 and vertically polarized base station antennas. For example, the horizontally polarized air-to-ground signal is received at 3 to 4, and 14 to 15 dB lower levels at terrestrial base stations employing slant 45, or vertically polarized receive antennas, respectively, as compared to the horizontal receive base station antenna.

¹³ Compute as 9 dB above interference level for SL45 antenna, plus 1 dB margin to prevent interference, plus a 6 dB increase for 2 signals & 2 aircraft within view, equals 16 dB above the required level. Therefore, the output power level of 0 dBm is 16 dB too high for the cellular band, and a -16 dBm output power limit is required for this case. Similarly, an output power limit of -9 dBm is required for the PCS band for this case. These output power levels are referenced to the input of the aircraft antenna.

However, since terrestrial networks utilize all these polarities in some part of the country, and vertical and Slant 45 antennas in all parts of the country, little improvements in isolation are achieved with using horizontally polarized air-to-ground signals. However, if the ground networks coordinate and agree to avoid using horizontal base station receive antennas nationwide on certain channels, then an isolation increase of 3 to 4 dB on average will be attained, if this polarization is used in the air-to-ground network. Therefore, only in cases where this is coordinated with the ground networks, will this method be effective. Also, it should be noted that even in this case, some cases will not result in any isolation benefits, due to signals bouncing off structures (and off the bottom of the airplane) and losing its polarization, essentially becoming randomly polarized. In this case it represents no added benefit or isolation.

b.) Smart or Directional Aircraft Antennas

Terrestrial base stations are most susceptible of receiving strong signals from air-to-ground systems between the vertical angles of 8 degrees to 50 degrees below the horizon (reference to aircraft). Therefore, if air-to-ground antennas are designed to significantly minimize the signals in these vertical angles, some isolation may be afforded to the ground systems. However, these improvements may be offset by the increased gain of the antennas, in addition to the aircraft antenna side lobes and reflections off the body of the aircraft. Therefore, this approach is difficult to achieve improvements in isolation, but may be worth additional investigation to fully understand the possibilities. For smart transmit antennas used in the aircraft, the only advantage is that it can potentially minimize the number of base stations with interference, however some base stations will always be within the maximum beam of the smart antenna because terrestrial sites are in all locations throughout the country and the airplane flight paths traverse the same areas. Also, if the terrestrial sites and air-to-ground base stations are co-located or located nearby, then even the narrowest beam smart antenna would be interfering with these terrestrial base stations.

c.) Smart Antennas Deployed in the Air-to-ground Base Stations

If the air-to-ground base stations utilize smart receive antennas, then additional link budget improvements can be achieved, which allows lower power operation for the airborne aircraft transmitter. Therefore, prior to the Commission considering any air-to-ground proposals to share cellular or PCS spectrum, smart antennas should be a requirement for all air-to-ground base stations sharing spectrum with ground networks to maintain the lowest power levels in the aircraft, and to minimize any impacts to the ground networks.

B. Interference Caused by Airborne Handsets & Pico Cells at Low Levels

1. Assessment of Airborne Handset Operation, Impact to Terrestrial Cellular & PCS Networks

To assess of the impact of airborne handsets and pico cells the results of the V-COMM flight and interference tests are used in this analysis. These flight tests are briefly described in the previous section of this report, and are submitted in the FCC record in the AirCell proceeding. These flight tests represent over 10,000 air-miles of flight testing of the AirCell air-to-ground system operating in cellular spectrum and the received signal levels at a variety of terrestrial base station antennas. Included are the flight altitudes of 2,000 feet to 35,000 feet above mean sea level (AMSL), and distances from the terrestrial base station from 2 mile to 135 miles away. The same received signal levels used in the previous section for analysis of the air-to-ground system is used in this section, which uses the 90% strongest signal levels received at the terrestrial base stations.

In addition, the same “unacceptable interference” level at terrestrial base stations is used in this analysis, which was described in the previous section of this report, which is -120 dBm. At this level of interference, it was observed in real-world base station tests that the operating margin for AMPS calls was reduced by 7 dB, for TDMA calls it was reduced by 3 dB, and for CDMA calls it was reduced by 1.6 dB. This represents a significant reduction in system coverage and capacity, particularly for in-building users. Therefore, the -120 dBm is considered the level of “unacceptable interference” for terrestrial base stations for this analysis. In addition, at least a 1 dB margin below this level is assumed to be needed to prevent unacceptable interference from occurring. Therefore, for the assessment of the airborne use of handsets operating in cellular or PCS spectrum, the airborne signals must be received at or below -121 dBm at the terrestrial cellular and PCS base stations, to prevent this level of interference from occurring.

For this airborne handset interference analysis, it is assumed that the onboard pico cell is controlling the power limit of the handset to a maximum power level of 0 dBm, with a 0 dBi handset antenna gain, resulting in a power of 0 dBm EIRP. This is the minimum power level for standard GSM handsets when operating in PCS spectrum. The minimum level for CDMA handsets is -50 dBm when operating in both cellular and PCS spectrum bands. It should be noted that the minimum power level for GSM, AMPS, and TDMA handsets operating in cellular spectrum is + 5 dBm, +8 dBm, and -4 dBm respectively. Therefore, some handsets operating in cellular spectrum cannot meet this 0 dBm level, without modifications to these handsets. However, disregarding the differences in output power levels, this analysis assumes that the handset output power level of 0 dBm is used for onboard pico cell operation. Also, a 0 dBi handset antenna gain is assumed, which represents a handset radiated power limit of 0 dBm EIRP.

The V-COMM flight tests used an AirCell aircraft antenna that is horizontally polarized and therefore, the received signal levels at the horizontally polarized (H-POL) base station antenna is used for this analysis of airborne handset and pico cell operation. In this way, the handset interference can be analyzed for cases where the airborne handset antenna and base station receive antenna are using the same polarization (i.e. cases where both will be aligned, either

vertically, or at a 45 degree angle). For the altitudes of 10,000 to 35,000 feet, the results of the jet aircraft are used, and for 2,000 to 5,000 feet the piston aircraft results are used in this analysis.

Analyzing the flight test results, the 90% signal levels received at the terrestrial base stations range from -75 to -98 dBm, for the AirCell air-to-ground system using an output power level of +16 dBm into the aircraft antenna, as shown in the table below.

Aircraft Type	Altitude (feet, AMSL)	AirCell Signals Received at Terrestrial BTS H-POL Antenna (90% Level) dBm	AirCell Signals (90% Level) Received at Terrestrial BTS when Aircraft is X from BTS	
			Miles	Vertical Degrees
Piston	2,000	-75	2	10.7
Piston	5,000	-85	5	10.7
Jet	10,000	-91	4 & 10	25.3 & 10.7
Jet	20,000	-94	19	11.3
Jet	35,000	-98	11	31.1

Table 4: AirCell Signals Received, Distances & Degrees to Terrestrial BTS

The worst case vertical angles from the aircraft to the terrestrial base stations are between 10 to 31 degrees (below the horizon). As outlined below, these same vertical angles represent the cases where the handset's signals can be expected to have no signal loss through the airplane cabin, for passengers using handsets at the window seats. Therefore, the same free-space propagation loss of AirCell signals from the aircraft to the base station is assumed to occur for this analysis with cellular and PCS airborne handsets, with no additional penetration losses for the airplane cabin.

The results of V-COMM's *Airplane Cabin Leakage Study* (submitted as an attachment with this report), is studied to assess the cellular and PCS signal leakage (loss or gain in signal) through the airplane cabin. As indicated in the V-COMM airplane leakage report, when considering the angles between the horizon and 40 degrees below the horizon, there will be no loss in signal strength through the airplane cabin for passengers using handsets at the window seats. In addition, in many cases, the signal leakage is actually increased through cabin windows. For the 737 aircraft, the increase in signal strength was measured to +3 to +4 dB, on average along the broadside (perpendicular to aircraft) radials for the vertical angles between the horizon and 40 degrees below the horizon. For the 767 airplane, the average airplane leakage was approximately 0 dB loss for cellular and PCS frequencies (within +/- 1 dB of no loss through aircraft cabin window), for the window seat tests along the broadside measurement radials. Therefore, for this analysis, the airplane signal leakage is assumed to be 0 dB loss (or no loss through the airplane cabin) for cellular and PCS frequencies, to assess the impact of airborne handset operation to the terrestrial networks.¹⁴ As indicated in the airplane signal leakage measurements, the airplane

¹⁴ To assess the impact for the worst case signal leakage the results for the 737 aircraft should be used, which represent an average increase of 3 to 4 dB through the airplane cabin window for the cellular and PCS bands. The FCC should consider these worst cases conditions for some airplanes in its analysis of the impact of an airborne handset to terrestrial base stations. However, the case for which 0 dB signal loss is occurring, is used for the analysis in this report for both cellular and PCS bands.

cabin leakage value of 0 dB is assumed for the angles from the horizon to 40 degrees below the horizon. For the angles of 50 to 90 degrees below the horizon (90 degrees is straight down), the airplane cabin loss is significantly more than these values, typically 10 to 20 dB losses through the airplane fuselage, and therefore is not considered in this analysis

For the V-COMM flight tests, the AirCell airborne units were operating with an output power level of +16 dBm, as referenced at the aircraft antenna. The antenna gain of the aircraft antenna is assumed to be representing a unity gain antenna providing 0 dBd gain, or +2 dBi antenna gain. Therefore, the AirCell airborne units were operating with a radiated power of +18 dBm EIRP. This is 18 dB stronger than the assumed handset power level of 0 dBm EIRP. Therefore, the receive signal levels from airborne handsets are assumed to be 18 dB lower than the AirCell signal levels received at the terrestrial base stations.

Adjusting the flight measurement data by 18 dB (to represent a 0 dBm EIRP handset), the received signal levels at terrestrial cellular and PCS base stations can be expected to be received as the levels indicated in the following table. For the PCS band, the path loss will have 7 dB of additional propagation loss as compared to the cellular band due to the differences in propagation of the two frequency bands.

Aircraft Altitude (feet, AMSL)	Received Signal Strength of Airborne Handset at 0 dBm EIRP, Received at Terrestrial BTS (dBm)	
	Cellular Band	PCS Band
2,000	-93	-100
5,000	-103	-110
10,000	-109	-116
20,000	-112	-119
35,000	-116	-123

Table 5: Airborne Handset Signals Received at Terrestrial BTS

These airborne handset signals are received at levels that are above the levels shown to cause unacceptable interference to terrestrial base stations, for all cases except for the 35,000 feet altitude with handsets operating in the PCS band. These airborne receive levels are for one co-channel signal and one aircraft in view of the terrestrial base station. For multiple aircraft and/or co-channel signals, even stronger signals are expected (i.e. for two aircraft or signals that are co-channel with a terrestrial base station, an increase in signal strength of 3 dB can be expected.)

For the case with one or two airborne handset that are co-channel with terrestrial base stations, the following tables show the expected receive levels at terrestrial base stations, in decibels (dB) above the unacceptable interference level of -120 dBm.

Aircraft Altitude (feet, AMSL)	Received Signal Strength from One Airborne Handsets at 0 dBm EIRP, in Decibels above BTS Unacceptable Interference level (dB)	
	Cellular Band	PCS Band
2,000	27	20
5,000	17	10
10,000	11	4
20,000	8	1
35,000	4	-3

Table 6: One Airborne Handset Signal Received, Above BTS Interference Level

Aircraft Altitude (feet, AMSL)	Received Signal Strength from Two Airborne Handsets at 0 dBm EIRP, in Decibels above BTS Unacceptable Interference level (dB)	
	Cellular Band	PCS Band
2,000	30	23
5,000	20	13
10,000	14	7
20,000	11	4
35,000	7	0

Table 7: Two Airborne Handset Signals Received, Above BTS Interference Level

As indicated in the tables above, the airborne handset signals received at terrestrial base stations rises to the level of unacceptable interference, for all cases except for the case with one PCS airborne handset at 35,000 feet. Therefore, due to the very strong receive signal levels that can be expected from airborne handsets, the FCC should not authorize this airborne service at the 0 dBm level, as it can cause substantial harmful interference to the terrestrial networks.

2. Airborne Handset & Pico Cell Operation above 10,000 feet

This section considers the case where airborne handsets and pico cells are only permitted for use above 10,000 feet in altitude. At 10,000 feet, the case with two airborne handsets shows that additional attenuation of the airborne handset signals is needed to prevent unacceptable interference to terrestrial networks. For airborne handsets operating at the radiated power level of 0 dBm EIRP and 10,000 feet, 15 dB of additional attenuation is needed for the cellular band, and 8 dB of additional attenuation is needed for the PCS band, in order to prevent unacceptable interference to the terrestrial networks (assumes 1 dB margin to prevent the interference).¹⁵

¹⁵ This represents the handset power limit of -15 dBm EIRP for the cellular band, and -8 dBm EIRP for the PCS band, to prevent unacceptable interference to the terrestrial networks. These power levels are significantly lower than the minimum power level used by many commercial handsets today.

3. Additional Attenuation for Airborne Handset Signals

Additional attenuation can be achieved through the following methods, to prevent unacceptable interference to terrestrial networks.

a.) Lower power handsets

Some handsets' minimum power level is less than 0 dBm. For example, TDMA handsets can operate to -4 dBm, and CDMA handsets can operate to -50 dBm. Also, sufficient power is needed to close the link for onboard pico cell operations. For example, CDMA handsets may need to operate at -20 dBm to close the link for many airplane pico cell operations. In addition, handsets can be modified to offer airplane friendly modes with minimum power levels that are less than the 0 dBm level by the required attenuation amounts given above.

b.) Airplane Window Shielding

As shown in our airplane leakage study, most of the signal is transmitting through the cabin windows. If airplanes are using windows shielding that sufficiently reduces the handset signal by 8 dB for the PCS band (or 15 dB for the cellular band), then the airborne handset operation at 0 dBm EIRP for two handsets at 10,000 feet is not expected to cause unacceptable interference to the terrestrial networks using the same spectrum.

c.) Frequency Coordination and Spectrum Leasing Arrangements

Frequency coordination and spectrum leasing arrangements may permit airborne operation at the 0 dBm power level (and possibly higher power levels) and at lower altitudes, in some cases where terrestrial networks agree and coordinate the appropriate frequencies for airborne operation at the expense of limiting the use of certain channels in the ground networks. These arrangements and agreements need to be considered on a case by case basis and to the extent any harmful interference is caused to an adjacent market cellular or PCS provider that is not in cooperation or agreement with the pico cell operator.

4. Multiple Airborne Handsets & Multiple Aircraft

Depending on the technology and frequencies supported by the onboard pico cell system, additional handsets used onboard will not always contribute to increase co-channel interference to ground networks if the pico cell operation is properly engineered. For example, up to 24 GSM handsets can be talking on 3 GSM channels (8 timeslots per channel), with each channel using a different 1.25 MHz channel of spectrum. In this case, only 1 signal would be co-channel with a ground CDMA network. Therefore, in some cases and if it is properly engineered, only 1 co-channel signal would be coming from each aircraft, toward the ground networks. (However, this may not be the case for wider bandwidth technologies such as UMTS that use 5 MHz wide bandwidths that have the potential to see more frequencies used by the airborne operations.)

In addition, a limited number of aircraft will be within view of the worst case air-to-ground angles toward the base station (having the least path loss, and occurring at the same time), due to the base station antenna pattern and handset signal leakage through the cabin at different incident angles below the horizon. (The worst case incident angles for terrestrial base station antennas depend on the respective path losses and antenna pattern discrimination values.)

For base stations near airports that can see many airplanes in the airport's landing patterns (generally at or below 10,000 feet), many aircraft can be visible and close to these base stations, which represents a highly sensitive interference case with multiple aircraft signals combining and adding to the noise arriving at these base stations. If pico cell operations were restricted to above 10,000 feet, this may prevent these cases from occurring.

It also should be noted that additional aircraft can be within view of terrestrial base stations however these may be: 1.) at higher altitudes (i.e. above 10,000 feet); 2.) received at azimuths that are greater than 30 degrees from the broadside of the aircraft, which reduces the signal leakage through the airplane cabin; 3.) received outside the horizontal main beam pattern of a sector antenna; or 4.) received at omni base station antennas that generally receive lower signal strengths due to the narrower vertical antenna pattern. All four of these cases would result in lower received signal levels as compared to the worst case handset at the window seat and base stations that are oriented broadside (perpendicular) to the aircraft's direction of flight.

For analysis purposes, this report only considers the cases with one or two aircraft (or two airborne handsets). If more than two aircraft are viewable by the base stations within the worst case incident angles and are co-channel with the terrestrial networks, then provisions should be made to address these cases.

5. Other Terrestrial Base Station Antennas

A variety of the most common terrestrial base station antennas were used in the V-COMM flight tests, which included one omni-directional antenna with approximately 11 dBi gain, and a variety of directional panel antennas with approximately 14 dBi of gain and 90 degree horizontal patterns. These are the most common antennas used in cellular and PCS systems. Also, some cellular and PCS systems use higher gain base station antennas (i.e. 17 dBi gain), however the additional gain is usually offset by a narrower vertical pattern that receives more signals coming from the horizon, with lower signals received above the horizon. Therefore, these higher gain base station antennas do not pose a more significant interference threat than the antennas used in the V-COMM flight tests. However, when considering some narrower horizontal beam-width base station antennas, for example 65 and 45 degree sector antennas, these antennas have wider vertical beam widths, and can be expected to receive signals that are approximately 1.5 to 2.5 dB stronger than similarly configured 90 degree sector antennas. However, in these cases, due to narrower horizontal beam width pattern, the likelihood of receiving signals from more than 1 aircraft is significantly less than the 90 degree sector antennas. Therefore, these base station antennas would represent slightly less signal received from one aircraft, as the more common 90 degree sector antenna could receive from two aircraft (i.e. +1.5 or +2.5 dB vs. +3 dB).

Therefore, these other base station antennas do not pose a more significant interference threat than the most commonly used base station sector 90 degree panel antenna, which was used in the V-COMM flight tests.

6. Interference Caused Onboard Pico Cells

Onboard pico cell transmissions will be operating on the base station forward-link spectrum and have the potential to interfere with cellular or PCS handsets on the ground. Therefore, a forward-link study is also needed to determine suitable power levels for onboard pico cell operation, and to ensure harmful interference is not caused to cellular or PCS handsets on the ground.

Initial studies indicate that onboard pico cells can operate at the same power level that non-interfering airborne handsets can operate, without causing unacceptable interference to terrestrial networks.^{16, 17} In addition, the same constraints and interference concerns addressed for airborne handsets (see sections above) also apply to airborne pico cells to prevent interference to ground networks.

In some cases the onboard pico cells may be able to operate at higher power levels (i.e. 10 dB higher than airborne handsets), if sufficient isolation and additional attenuation is provided by the pico cell antenna and placement within the cabin to minimize signal leakage outside the cabin toward the ground. For example, as shown in the result of V-COMM's *Airplane Cabin Leakage Study*, two pico cell locations provided at least 6 to 10 dB of signal attenuation for PCS frequencies propagating through the cabin of the aircraft. In addition, there may be some discrimination losses in the horizontal pattern of the pico cell antenna with more energy directed toward the center aisle of the aircraft and less energy toward the windows, providing additional attenuation toward the windows. In this case, the onboard pico cell may be able to operate at radiated power levels 10 dB higher levels than non-interfering airborne handsets. In example, if it is shown that airborne handsets operating at 0 dBm EIRP in a shielded cabin will not interfere with ground networks, then the pico cell in this case would be permitted to operate at +10 dBm EIRP.

¹⁶ The antenna gain pattern of handsets and terrestrial base stations are expected to have approximately the same gain for the vertical angles above the horizon that are pointing toward airplanes in flight. Terrestrial base antennas have more antenna gain pointed at the horizon (i.e. 14 dBi vs. 0 dBi). However when considering the base station line loss of 1 to 2 dB and the reduced antenna gain at elevation angles above the horizon, the received signals at terrestrial base stations are similar to levels received on a 0 dBi handset antenna on the ground.

¹⁷ Handsets on the ground will have greater visibility to aircraft than terrestrial base station sector antennas, due to much wider vertical and horizontal antenna main beam patterns. For this reason, handsets are expected to have additional aircraft within their main beam patterns, as compared to base stations, and receive increased signal levels. Assuming that 2 or 2.5 times the number of aircraft signals can be received at handsets, the signal strength can increased by 3 to 4 dB at handsets (i.e. antenna azimuths of 180 to 225 degrees, plus additional vertical angles). Also, the noise figures of handsets are about 6 to 7 dB, as compared to base stations that are approximately 3 dB. Therefore, handsets are expected to have unacceptable interference levels that are roughly 3 to 4 dB higher (less sensitive) than base stations. Thus, the net of effect of these two differences (noise figures & antenna main beams) is expected to result in similar airborne signal levels received at handsets, as compared to terrestrial base stations.

C. Interference Caused by Airborne Handsets at Maximum Power, Not Under Control of the Onboard Pico Cell

This section addresses the case when the onboard pico cell does *not control* the airborne handsets. When this occurs, the airborne handsets will most likely be operating at or near its maximum power level (i.e. +30 dBm), due to the increased distance from the serving terrestrial sites. At these times, the airborne handset will transmit at much higher power levels (i.e. 1,000 times stronger than a handset at 0 dBm) and can cause significant harm to thousands of terrestrial sites along its flight path that are sharing the same spectrum. Therefore, to prevent full power airborne handsets from severely degrading the reliability of terrestrial networks, the pico cell must control all handsets (types, bands & technologies) all the time in order for it to be permitted. In addition, airborne handsets operating at maximum power levels could interfere with airplanes' communication, navigation, and electronic equipment.

1. Multiple Spectrum Bands and Handset Technologies Should be Supported by the Onboard Pico Cell

Multiple spectrum bands and handset technologies will need to be supported by the onboard pico cell. All handset types that are not supported will attempt to access the ground systems, and operate at much higher power levels (i.e. +30 dBm EIRP and higher). Therefore, the onboard pico cell must support the following spectrum bands, handset technologies, and wireless services:

- Spectrum Bands: Cellular, PCS, SMR, and AWS (700, 1700 & 2100 MHz) Bands
- Wireless Technologies:
 - Voice: CDMA, TDMA, GSM, AMPS, IDEN, 3G, UMTS
 - Data: SMS, EMS, GPRS, EDGE, 1XRTT, EVDO
- Wireless Services: Voice, Data, E-mail, Messaging, Push-to-talk, Voice Mail, Location, Picture, Video

To the extent that other services (i.e. data services) utilize other channels of the terrestrial base stations, they will need to be supported as well, otherwise airborne handsets & PC data cards (i.e. EVDO or EDGE data cards) will attempt to access ground networks at full power levels.

Furthermore, all handsets need to be supported for reasons that flight attendants and passengers cannot distinguish between supported and non-supported phone types and spectrum bands. Therefore, if any phones are supported, all phones need to be supported, to prevent airborne handsets from accessing the ground networks at maximum power. This drastically increases the size and complexity of the onboard pico-cell, particularly when considering the multiple spectrum bands and technologies used by today's CMRS handsets.

As an alternative to supporting all handsets, modifications can be made to incorporate an "airplane friendly mode" in the handsets, as described in Section 4.

2. Handset's System Search Algorithm Will Access Ground Networks, Not the Onboard Pico Cell

When handsets are powered on in-flight, they are programmed to search for their home and preferred systems before looking for any other compatible spectrum bands and technologies. Because terrestrial signals can penetrate aircraft windows with no losses and be received at strong receive levels (even at high altitudes), the handsets will access and place calls on the terrestrial system rather than search for and access the onboard pico cell. And, due to the increased path losses to the terrestrial system, the airborne handsets (not under control of the pico cell) will most likely operate at their maximum power levels (i.e. +30 dBm). This is a major compatibility issue for pico cells attempting to control handsets onboard, even in cases where all spectrum bands and technologies are supported.

3. Roaming Agreements and Preferred Roaming Lists (PRL Lists)

a.) Roaming Agreements with Terrestrial Service Providers

Roaming agreements will be necessary with all the supported terrestrial service operators to validate and authenticate users, prevent fraudulent use, and facilitate automatic billing arrangements. Otherwise, only credit card operation will be supported.

b.) Handsets Preferred Roaming Lists (PRL Lists)

Handsets using the supported technologies will require updated PRL lists and updated programming to find and access the onboard pico cell. Otherwise, many phones will not accept system IDs used by the pico cell system, and will not lock-onto its signal. In these cases, the phones will continue searching for its terrestrial signal and attempt to connect to the terrestrial system much farther away, and most likely at or near the handset's maximum power level up to 1 watt (+30 dBm) EIRP. Again, this situation will cause significant harmful interference to the ground networks, and must be avoided at all costs. To address this issue, service providers will need to update the PRL lists and programming modes for all phones in their networks that can be used onboard airplanes in-flight.

4. Advantages of an "Airplane Friendly Mode" Implemented in the Handsets

Modifications to handsets can be made to incorporate an "airplane friendly mode" in handsets. This can incorporate a visual indication that airborne handsets are controlled by the onboard pico-cell, and are not transmitting at much higher power levels (i.e. +30 dBm) to a terrestrial network. The visual indication can be a common icon on the phone's display, or a display light on the top of the phone to indicate it is under positive control of the onboard pico cell.

Under this scenario, flight attendants and passengers will know which phones are supported and can be used. They will also have positive confirmation that the pico cell is controlling the power to appropriate levels to prevent harmful interference to terrestrial networks. This implementation can prevent non-supported handsets from being used in-flight. This assumes that only supported phones (showing the appropriate indications) will be used in-flight, and the system is not abused.

In addition to modifications that incorporate an “airplane friendly mode”, handsets can be modified to offer even lower output power levels in these airborne modes. For example, GSM handsets can incorporate a switch-able transmit attenuator or lower output levels to limit onboard transmissions to –10 or –20 dBm EIRP. This will decrease the signals toward the ground networks, and may facilitate airborne operation at lower altitudes.

5. Aircraft Window Shielding

Aircraft window shielding can assist with mitigating two problems associated with airborne operation. First, window shielding will reduce the terrestrial signals received in the cabin, which helps to prevent handsets from locking onto their home terrestrial networks while in-flight. Second, it may allow higher power operation within the cabin or allow for airborne service at lower altitudes, due to the additional attenuation provided by the window shielding, which can be on the order of 10 to 30 dB depending on the RF shielding materials and implementation. However, this option has the drawback of reducing the terrestrial signals in the cabin when the airplane is on the ground, which may prevent terrestrial calls from being placed when inside aircraft taxiing and at airport gates.

6. Cell Site Blocking, Emulation & Jamming

Using cell site blocking, emulation, or noise floor elevation (noise jamming) equipment can be part of a solution to limit the ability for handsets to receive terrestrial signals in-flight. This can be turned on/off at certain altitudes in conjunction with pico-cell operation. Cell site blocking and emulation equipment may increase the size, cost and complexity of the onboard pico cell, and may not be practical. Noise floor jamming equipment may raise the noise floor enough to prevent handsets from acquiring outside terrestrial signals however this option may cause increased forward-link interference to ground networks and may interfere with aircraft communication and navigation equipment.¹⁸ In addition, the noise jamming equipment may increase the noise floor in all bands (including the pico cell channels) and require airborne handsets to transmit at higher levels to overcome the higher noise levels, which can increase the likelihood interfering with terrestrial networks.

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In summary, all handsets need to be controlled by the onboard pico cell, and all handsets must be prevented from acquiring terrestrial signals in-flight. Otherwise, airborne handsets will acquire terrestrial signals and operating at maximum power levels (i.e. +30 dB), and cause significant harm to terrestrial networks. Some potential mitigating factors to facilitate control of airborne handsets include window shielding, noise floor jamming equipment, handset airplane friendly modes and management of staff, updated programming modes and PRL lists, roaming agreements, cooperation of service providers, setting policies and procedures, education, lower power limits, and restricting airborne service at lower altitudes. Lastly, prior to the authorization of airborne handsets and pico cell operation, in-flight tests and analyses should be studied extensively to ensure the ground networks are fully protected from unacceptable interference.

¹⁸ Also, it should be noted that FCC rules and regulations do not permit the use of cell site and noise floor jamming equipment in airborne operation or in ground networks.

D. Other Issues Need to Be Addressed Prior to Adoption of Airborne Handset Operation

In addition to the technical issues and cases of interference outlined in the previous sections of this report, other issues also need to be addressed prior to the adoption of airborne handsets and pico cell operation. These issues are addressed below.

1. FAA & Airline Approvals Required

The FAA and the airlines must certify onboard pico cell equipment and handset operation are authorized for such uses, and confirm that neither will interfere with aircraft electronic equipment. Of particular concern are handsets transmitting at maximum power levels (i.e. +30 dBm) inside the cabin, for handsets that are not controlled by the pico cell and attempt to access the ground networks in-flight. The RTCA is currently studying the impact and potential interference caused by personal electronic devices on aircraft electronic equipment.

2. Cellular Band is Less Suitable than PCS Band for Airborne Operation

The cellular band is less suitable than the PCS band for airborne handset and pico cell operation due to the lower propagation path loss associated with the cellular band. The cellular band has 7 dB less propagation losses than the PCS band. In addition, the minimum power level for GSM handsets operating in the cellular band is 5 dB higher than GSM handsets operating in the PCS band (+5 dBm vs. 0 dBm). Thus, the cellular band represents the larger interference threat to terrestrial systems, with signals that are received 12 dB stronger than airborne signals operating in the PCS band. For these reasons, airborne operation should favor using PCS spectrum rather than cellular spectrum.

3. International & World Phones

Handsets from other countries will most likely not be supported by the onboard pico cell, except for the few cases with world phones supporting the U.S. spectrum bands. Non-world international phones will not see their home systems/bands and show “no service”. These phones will not be co-channel with U.S. terrestrial networks, and consequently will not interfere with them.

4. Off Shore Operation

Operation of pico-cell aboard airplanes flying over the Atlantic or Pacific Oceans at some distance off shore (i.e. 50+ miles off shore) will have little likelihood of interfering with terrestrial systems when the power level is maintained to 0 dBm and flying above 10,000 feet. In this case, sufficient attenuation of the airborne signal is expected due to the propagation path loss and the alignment/signal-leakage of the aircraft in almost all cases.

5. Education of Airborne Handset Use

Wireless customers, passengers, and flight attendants need to be educated as to the appropriate rules and procedures to be followed for airborne operation to ensure that interference to ground networks will not occur. Customers need to be educated as to the airborne services provided, rates, and any special operating modes needed for airplane use. Also, Airline procedures & policies need to be developed for safe airborne operation.

6. Comprehensive Real-World Testing is Needed

Extensive and comprehensive testing is needed to fully understand the interference potential of the proposed airborne wireless systems prior to authorization.

7. CMRS Licensees Must Be Involved

CMRS licensed operators must be involved. They are needed to address and resolve the many handset and operational issues associated with airborne uses of CMRS spectrum, to ensure airborne handsets are controlled by the onboard pico cell and not operating at maximum power levels, and to ensure that the reliability of the terrestrial networks and utility of spectrum is not deteriorated.

CMRS licensed operators can also provide spectrum leasing, roaming agreements & connections, handset re-programming issues, updated handset PRL lists, necessary modifications to handsets (including airplane friendly modes and power limiting airborne handsets), customer & airline education, coordination and resolution of problems, frequency coordination and selection, testing and verification, and other arrangement to address all the potential interference issues that can result from such implementations. In addition, the service providers are the more experienced and capable of successfully implementing other critical services and wireless technologies such as CALEA, Priority Access Systems, E911 Phase 2 location services (assisted GPS and network based solutions), feature compatibility with ground networks, TTY/ hearing aid compatibility, among other wireless operating modes.

Appendix A – Company Information & Biographies

V-COMM is a leading provider of quality engineering and engineering related services to the worldwide wireless telecommunications industry. V-COMM's engineering staff is experienced in Cellular, Personal Communications Services (PCS), Enhanced Specialized Mobile Radio (ESMR), Paging, Wireless Data, Microwave, Signaling System 7, and Local Exchange Switching Networks. We have provided our expertise to wireless operators in engineering, system design, implementation, performance, optimization, and evaluation of new wireless technologies. Further, V-COMM was selected by the FCC & Department of Justice to provide expert analysis and testimony in the NextWave and Pocket Communications Bankruptcy cases. V-COMM has offices in Blue Bell, PA and Cranbury, NJ and provides services to both domestic and international markets. For additional information, please visit V-COMM's web site at www.vcomm-eng.com.

BIOGRAPHIES OF SENIOR MEMBERS OF V-COMM, L.L.C.

Dominic C. Villecco President and Founder

Dominic Villecco, President and founder of V-COMM, is a pioneer in wireless telecommunications engineering, with 22 years of executive-level experience and various engineering management positions. Under his leadership, V-COMM has grown from a start-up venture in 1996 to a highly respected full-service consulting telecommunications engineering firm.

In managing V-COMM's growth, Mr. Villecco has overseen expansion of the company's portfolio of consulting services, which today include a full range of RF & Network design, engineering & support; network design tools; measurement hardware; and software services; as well as time-critical engineering-related services such as business planning, zoning hearing expert witness testimony, regulatory advisory assistance, and project management.

Before forming V-COMM, Mr. Villecco spent 10 years with Comcast Corporation, where he held management positions of increasing responsibility, his last being Vice President of Wireless Engineering for Comcast International Holdings, Inc. Focusing on the international marketplace, Mr. Villecco helped develop various technical and business requirements for directing Comcast's worldwide wireless venture utilizing current and emerging technologies (GSM, PCN, ESMR, paging, etc.).

Previously he was Vice President of Engineering and Operations for Comcast Cellular Communications, Inc. His responsibilities included overall system design, construction and

operation, capital budget preparation and execution, interconnection negotiations, vendor contract negotiations, major account interface, new product implementation, and cellular market acquisition. Following Comcast's acquisition of Metrophone, Mr. Villecco successfully merged the two technical departments and managed the combined department of 140 engineers and support personnel.

Mr. Villecco served as Director of Engineering for American Cellular Network Corporation (AMCELL), where he managed all system implementation and engineering design issues. He was responsible for activating the first cellular system in the world utilizing proprietary automatic call delivery software between independent carriers in Wilmington, Delaware. He also had responsibility for filing all FCC and FAA applications for AMCELL before it was acquired by Comcast.

Prior to joining AMCELL, Mr. Villecco worked as a staff engineer at Sherman and Beverage (S&B), a broadcast consulting firm. He designed FM radio station broadcasting systems and studio-transmitter link systems, performed AM field studies and interference analysis and TV interference analysis, and helped build a sophisticated six-tower arrangement for a AM antenna phasing system. He also designed and wrote software to perform FM radio station allocations pursuant to FCC Rules Part 73.

Mr. Villecco started his career in telecommunications engineering as a wireless engineering consultant at Jubon Engineering, where he was responsible for the design of cellular systems, both domestic and international, radio paging systems, microwave radio systems, two-way radio systems, microwave multipoint distribution systems, and simulcast radio link systems, including the drafting of all FCC and FAA applications for these systems.

Mr. Villecco has a BSEE from Drexel University, in Philadelphia, and is an active member of IEEE. Mr. Villecco also serves as an active member of the Advisory Council to the Drexel University Electrical and Computer Engineering (ECE) Department.

Relevant Expert Witness Testimony Experience:

Over the past five years, Mr. Villecco had been previously qualified and provided expert witness testimony in the states of New Jersey, Pennsylvania, Delaware and Michigan. Mr. Villecco has also provided expert witness testimony in the following cases:

- United States Bankruptcy Court
- NextWave Personal Communications, Inc. vs. Federal Communications Commission (FCC) **
- Pocket Communications, Inc. vs. Federal Communications Commission (FCC) **

** In these cases, Mr. Villecco was retained by the FCC and the Department of Justice as a technical expert on their behalf, pertaining to matters of wireless network design, optimization and operation.

David K. Stern
Vice President and Co-Founder

David Stern, Vice President and co-founder of V-COMM, has over 20 years of hands-on operational and business experience in telecommunications engineering. He began his career with Motorola, where he developed an in-depth knowledge of wireless engineering and all the latest technologies such as CDMA, TDMA, and GSM, as well as AMPS and Nextel's iDEN.

While at V-COMM, Mr. Stern oversaw the design and implementation of several major Wireless markets in the Northeast United States, including Omnipoint - New York, Verizon Wireless, Unitel Cellular, Alabama Wireless, PCS One and Conestoga Wireless. In his position as Vice President, he has testified at a number of Zoning and Planning Boards in Pennsylvania, New Jersey and Michigan.

Prior to joining V-COMM, Mr. Stern spent seven years with Comcast Cellular Communications, Inc., where he held several engineering management positions. As Director of Strategic Projects, he was responsible for all technical aspects of Comcast's wireless data business, including implementation of the CDPD Cellular Packet Data network. He also was responsible for bringing into commercial service the Cellular Data Gateway, a circuit switched data solution.

Also, Mr. Stern was the Director of Wireless System Engineering, charged with evaluating new digital technologies, including TDMA and CDMA, for possible adoption. He represented Comcast on several industry committees pertaining to CDMA digital cellular technology and served on the Technology Committee of a wireless company on behalf of Comcast. He helped to direct Comcast's participation in the A- and B-block PCS auctions and won high praise for his recommendations regarding the company's technology deployment in the PCS markets.

At the beginning of his tenure with Comcast, Mr. Stern was Director of Engineering at Comcast, managing a staff of 40 technical personnel. He had overall responsibility for a network that included 250 cell sites, three MTSOs, four Motorola EMX-2500 switches, IS-41 connections, SS-7 interconnection to NACN, and a fiber optic and microwave "disaster-resistant" interconnect network.

Mr. Stern began his career at Motorola as a Cellular Systems Engineer, where he developed his skills in RF engineering, frequency planning, and site acquisition activities. His promotion to Program Manager-Northeast for the rapidly growing New York, New Jersey, and Philadelphia markets gave him the responsibility for coordinating all activities and communications with Motorola's cellular infrastructure customers. He directed contract preparations, equipment orders and deliveries, project implementation schedules, and engineering support services.

Mr. Stern earned a BSEE from the University of Illinois, in Urbana, and is a member of IEEE.

Sean Haynberg
Director of RF Technologies

Sean Haynberg, Director of RF Technologies at V-COMM, has over 15 years of experience in wireless engineering. Mr. Haynberg has extensive experience in wireless system design, implementation, testing and optimization for wireless systems utilizing CDMA, TDMA, GSM, AMPS and NAMPS wireless technologies. In his career, he has conducted numerous first office applications, compatibility & interference studies, and new technology evaluations to assess, develop and integrate new technologies that meet industry and FCC guidelines. His career began with Bell Atlantic NYNEX Mobile, where he developed an in-depth knowledge of wireless engineering.

While at V-COMM, Mr. Haynberg was responsible for the performance of RF engineering team supplying total RF services to a diverse client group. Projects varied from managing a team of RF Engineers to design and implement new a PCS wireless network in the NY MTA; to the wireless system design & expansion of international markets in Brazil and Bermuda; to system performance testing and optimization for numerous markets in the north and southeast; to the development and procurement of hardware and software engineering tools; to special technology evaluations, system compatibility and interference testing. He has also developed tools and procedures to assist carriers in meeting compliance with FCC rules & regulations for RF Safety, and other FCC regulatory issues. In addition, Mr. Haynberg was instrumental in providing leadership, technical analysis, engineering expertise, and management of a team of RF Engineers to deliver expert-level engineering analysis & reporting on behalf of the FCC & Department of Justice, in the NextWave and Pocket Communications Bankruptcy proceedings.

Prior to joining V-COMM, Mr. Haynberg held various management and engineering positions at Bell Atlantic NYNEX Mobile (BANM). He was responsible for evaluating new technologies and providing support for the development, integration and implementation of first office applications (FOA), including CDMA, CDPD, and RF Fingerprinting Technology. Beyond this, Haynberg provided RF engineering guidelines and recommendations to the company's regional network operations, supported the deployment and integration of new wireless equipment and technologies, including indoor wireless PBX/office systems, phased/narrow-array smart antenna systems, interference and inter-modulation analysis and measurement, and cell site co-location and acceptance procedures. He was responsible for the procurement, development and support of engineering tools for RF, network and system performance engineers to enhance the system performance, network design and optimization of the regional cellular networks. He began his career as an RF Engineer responsible for the system design and expansion of over 100 cell sites for the cellular markets in New Jersey, Philadelphia, PA; Pittsburgh, PA; Washington, DC; and Baltimore, MD market areas.

Mr. Haynberg earned a Bachelor of Science degree in Electrical Engineering with high honors, and attended post-graduate work, at Rutgers University in Piscataway, New Jersey. While at Rutgers, Mr. Haynberg received numerous honors including membership in the National Engineering Honor Societies Tau Beta Pi and Eta Kappa Nu. In addition, Mr. Haynberg has qualified and provided expert witness testimony in the subject matter of RF engineering and the operation of wireless network systems for many municipalities in the State of New Jersey.